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ABSOLUTE CONCENTRATIONS OF THE EARTH ATMOSPHERE IONIC COMPONENTS IN THE 100 — 200 KM ALTITUDE RANGE

(Absolyutnyye kontsentratsii ionnykh komponent atmosfery Zemli na vysotakh ot 100 do 200 km)

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Measurements in the upper atmosphere of the mass spectrum of positive ions with the help of a rocket-born radio-frequency mass spectrometer usually contribute data on the relative concentration of ions with different masses. The obtention of information on absolute ion concentrations by means of the mass-spectrometer method is possible in principle, but it is beset with a series of experimental difficulties. That is why direct measurements of electron concentration, conducted aboard the rocket simultaneously with the mass-spectrometric measurements are of great significance. The combination of mass-spectrometric data on ion composition with the obtained electron density profiles allows to determine the dependence on height of the concentration of ions with different masses. Such kind of data are important for the clarification of various questions bearing on chemistry and photochemistry of Earth's upper atmosphere and ionosphere.

Contrary to similar measurements carried out by USA investigators [1 — 3], most of rochet-born mass-spectrometric ion meansurements in the USSR are accompanied by simultaneous electron concentration measurements by radiotechnical means aboard the same rocket. The electron profiles brought out in [4], and which are the result of measurements during the 22 July 1959 and 15 June 1960 rocket launchings, have been utilized for the processing of mass-spectrometric measurements.

The method of measurements in a separating container and the basic results concerning the relative ion composition, obtained during the preceding rocket launchings (1957 — 1959) have been published earlier, (see ref. [5]).

The computation of the absolute concentrations of ions was effected with the aid of the correlation

which is valid at fulfillment of the following assumptions :

1. The sum of positive ion concentrations is equal to the electron concentr. $\Sigma[M_k^+] = n_e$, i. c. the negative ions are absent in the atmosphere. This assumption may apparently be valid for the daytime ionosphere.

2. The sum of ion peak amplitudes in the mass-spectrometer is proportional to the aggregate concentration of positive ions :

This corresponds to the absence of ions, whose mass does not reach within the device's range : 1 — 4 and 10 — 56 atomic units of mass. Such an assumption is not subject to serious doubts either.

3. The ratio of ion peaks' amplitudes in the spectrum is equal to the ratio of corresponding ions' concentrations in the atmosphere :

$$\frac{i_{M_1^+}}{i_{M_2^+}} = \frac{[M_1^+]}{[M_2^+]} .$$

The last correlation is equivalent to the assumption of absence of discrimination of ions with various masses in the mass-spectrometer. Factually it is not quite true though, for there apparently must be some some form of discrimination in the radio-frequency analyzer. It is difficult to make at present a rigid quantitative account of this phenomenon, and therefore the discrimination is discounted in the following Tables of ion concentrations.

This may have the stongest effect upon the values of atomic oxygen O^+ and atomic nitrogen N^+ ion concentrations, which are probably somewhat underrated and may only be considered correct with a precision to the factor 2. The factual concentrations of N_2^+, NO^+ and O_2^+ molecular ions cannot strongly differ from those brought out in the Tables, inasmuch as their masses differ little from one another, and the discrimination effects must be practically absent.

During the rocket launching on 15 June 1960, a type MX-6403 ion radio-frequency mass-spectrometer was installed in a separating container; it was different from the earlier-applied instruments [6, 7], being of greater sensitivity, and of somewhat smaller size and weight. Its mass range was within the 1 – 4 and 10 – 56 a.m.u. range. Owing to the great sensitivity of the MX-6403 device, ionic components, present at comparatively small concentrations, could be reliably registered alongside with the basic components of the ionosphere : NO^+, O_2^+ and O^+ ions. Some of the results obtained at that rocket launching have already been published. So, the question of detection of ions of extra-terrestrial origin is discussed in detail in references [8, 9], (Ma, Ca, Fe), and so is that of their absolute concentration determination. Reference [10] brings forth data on concentrations of atomic and molecular nitrogen ions.

The current paper brings forth data on absolute concentrations of all ions, reliably identified with the ionospheric components, i.e. ions with $M = 14$ (N^+), $M = 16$ (O^+), $M = 28$ (N_2^+, and possibly Si^+ in the 100 – 200 km region), $M = 30$ (NO^+) and $M = 32$ (O_2^+).

Aside from the designated ions, ions with mass numbers $M = 11$ (B^+) and $M = 12$ (C^+) were also registered on 15 June 1960. Their concentrations at 200 km were respectively $3 \cdot 10^3$ and $3 \cdot 10^2 cm^{-3}$. As far as is known, no ions with such mass numbers have to-date been registered in the atmosphere. The character of amplitude variation of these ions' mass peaks with altitude shows that they may be related to rocket contamination (this has been examined in detail in [5]); their reference to container contamination is also quite doubtful.

Questions linked with the occurrence of these "unusual" ions and the detailed results of measurements obtained at 15 June 1960 rocket launching are to be discussed further.

Ions with M = 18 (H_2O^+) were registered during that launching, just as in the preceding one in 1959 [5] in the most reliable way. Their concentration is not compiled in the Tables, for H_2O^+ ions cannot be reliably identified with the atmosphere constituents as yet. Let us point out however, that on June 15, 1960 the concentration of H_2O^+ ions at 200 km altitude was about $2 \cdot 10^4$ cm^{-3}, and during the 22 July 1959 rocket laun $[H_2O^+] \approx 3 \cdot 10^{-3}$ см$^{-3}$] was registered at the same altitude. These figures may offer interest in the light of registration by USA scientists of ions with M = 18, and of the ensuing discussion [1 – 3]

T A B L E **1**

Concentration of positive ions and electrons (in 10^3 cm^{-3} units) in the atmosphere on 15 June 1960 in the morning. Height of the Sun was 15°. Container's trajectory summit – 208 km.

Altitude in km	100	105	110	120	130	140	150	160	170	180	190	200
n_e	40	95	80	90	85	90	100	120	165	190	210	245 *
$[Fe^+]$	—	15**	—	—	—	—	—	—	—	—	—	—
$[Ca^+]$	Δ	0,5	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
$[O_2^+]$	5,0	—	19	30	35	39	40	42	52	46	45	49
$[NO^+]$	35	—	61	60	50	50	56	65	87	91	94	92
$[N_2^+]$	Δ	Δ	Δ	1,7***	Δ	Δ	Δ	0,5	0,7	1,1	1,7	2,7
$[Mg^+]$	Δ	14	1,0	0,4	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
$[O^+]$	Δ	Δ	Δ	Δ	Δ	1,0	4,0	12,0	25	46	75	125
$[N^+]$	Δ	Δ	Δ	Δ	Δ	Δ	Δ	0,1	0,2	0,26	0,32	0,36
The concentration of H and He ions, and also that of ions marked Δ, do not exceed the following values at respective heights	0,4	0,34	0,16	0,2	0,2	0,2	0,18	0,18	0,24	0,22	0,26	0,3

* Extrapolation. ** Orientation digit: at altitudes greater than 105 km $[Fe^+] < 3 \cdot 10^2$ cm^{-3}. *** Possibly, Si^+

The variations of ion concentration with altitude for the 22 July 1959, and 15 June 1950 flights are compiled in Tables 1 and 2.

Utilized were all the spectra obtained in the ascending branch of container's trajectory, excluding the region of its maximum, or summit (8 – 11 km above 200 km), as there is a danger, that because of rocket's gas emission, the composition will be strongly distorted [5]. The values of relative ion concentrations were takem from smoothened experimental curves. Inasmuch as the scattering of the experimental points is small for the basic components, and two-three to eight spectra are obtained in a 10 km interval, the random measurement errors are considered inessential. As to the possible systematic errors, reference to them was made above.

TABLE 2

Concentrations of positive ions and electrons (in 10^3 cm^{-3} units) in the morning atmosphere of July 22, 1959. Height of the Sun : 0^o. Container's trajectory summit : 211 km.

Altitude in km	95	100	110	120	130	140	150	160	170	180	190	200	210
n_e	20	23	19	30	42	41	42	45	46	52	60	70	80*
$[O_2^+]$	Δ	Δ	Δ	3,5	8,0	10	11	13	14	16	18	20	21
$[NO^+]$	Δ	23	19	26,5	34	31	31	31	30	32	36,5	40	56
$[O^+]$	Δ	Δ	Δ	Δ	Δ	Δ	Δ	1,0	2,0	4,0	6,5	10	12
The concentration of H and He ions, and also that of ions marked Δ, do not exceed the following values at respective heights	0,5	2,3	1,3	0,6	0,4	0,7	1,4	0,5	0,5	0,8	0,5	0,5	0,6

* Extrapolation

TABLE 3

Concentration of positive ions and electrons (in 10^3 cm^{-3} units) in the evening atmosphere of 9 September 1957. Sun setting : 6^o. Container's trajectory summit : 206 km.

	105	140	190	200	205
n_e	10	~ 10	~ 20	~ 40	~ 40
$[NO^+]$	10	9	16	33	29
$[O_2^+]$	< 1,5	~ 1	1,5	< 4	~ 1
$[O^+]$	< 1,5	< 1,5	3	7	10

In order to compare the results of morning and daytime measurements with those of the evening, compiled are in Table 3 concentrations of ions, registered in the course of the 9 September 1957 evening rocket launching [5]. Graphs of electron concentration with altitude for that launching are brought out in reference [11]. Inasmuch as the quality of mass-spectrograms obtained in the 9 Sept. 1959 launching is rather low (comparatively high noise level), while the number of obtained spectra is small, the concentrations of O^+ and O_2^+ ions in Table 3 may be considered as correct only with a precision to the factor 2. Being so far unique of their kind, these data may however offer interest.

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***** THE END *****

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References follow..

REFERENCES

1. C. Y. JOHNSON, J. P. HEPPNER, J. C. HOLMES, E. B. MEADOWS. Ann. Géophysique, 14, 475, 1958.
2. C. Y. JOHNSON, J. C. HOLMES., Space Research, v. I, Ed. H. Kalman page 417, Amsterdam 1960.
3. C. Y. JOHNSON. Ann géophysique., 17, 100, 1961.
4. V. A. RUDAKOV. Sb."ISZ" (AES), vyp.10, p. 102, 1961 (NASA TTF-8162)
5. V. G. ISTOMIN. Ibid. vyp.7, p.64, 1961.
6. V. G. ISTOMIN. Ibid. vyp.3, p.98, 1959.
7. V. A. PAVLENKO, A. E. RAFAL'SON, M. E. SLUTSKIY & AL. Pribory i tekhnika eksperimenta, No. 6, 89, 1960.
8. V. G. ISTOMIN. Dokl. A.N.SSSR, Tom 136, 1066, 1961. (NASA TT F-69)
9. V. G. ISTOMIN. Sb."ISZ" (AES), current v.11, 1961 (NASA TT F-8220)
10. V. G. ISTOMIN. Dokl. A.N.SSSR, 137, 1102, 1961 (NASA TT F- 8025)
11. K. I. GRINGAUZ. Dokl. A. N. SSSR, 120, 1234, 1958. also Sb"ISZ" (AES), vyp.1, p.62, 1958.